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UTILITY PATENT APPLICATION TRANSMITTAL

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Attorney Docket No.	15-CT-4697
First Named Inventor or Application Identifier	Senzig, et al.
Title	IMAGING SYSTEM FOR GENERATING HIGH QUALITY IMAGES
Express Mail Label No.	EL319727646US

APPLICATION ELEMENTS
See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: **Assistant Commissioner for Patents**
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1. [X] Fee Transmittal Form (e.g., PTO/SB/17)
(Submit an original, and a duplicate for fee processing)
2. [X] Specification [Total Pages] 20
(Preferred arrangement set forth below)
- Descriptive title of the Invention
- Cross References to Related Applications
- Statement Regarding Fed sponsored R & D
- Reference to Microfiche Appendix
- Background of the Invention
- Brief Summary of the Invention
- Brief Description of the Drawings (if filed)
- Detailed Description
- Claim(s)
- Abstract of the Disclosure
3. [X] Drawing(s) (35 USC 113) [Total Sheets] 9
4. Oath or Declaration [Total Pages] 4
   a. [X] Newly executed (original or copy)
   b. [ ] Copy from a prior application (37 CFR 1.63(d))
   (for continuation/divisional with Box 17 completed)
   [Note Box 5 below]
      i. [ ] DELETION OF INVENTOR(S)
      Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
5. [ ] Incorporation by Reference (useable if Box 4b is checked)
The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.
6. [ ] Microfiche Computer Program (Appendix)
7. Nucleotide and/or Amino Acid Sequence Submission
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ACCOMPANYING APPLICATION PARTS

8. [X] Assignment Papers (cover sheet & document(s))
9. [ ] 37 CFR 3.73(b) Statement (when there is an assignee) [X] Power of Attorney
10. [ ] English Translation Document (if applicable)
11. [ ] Information Disclosure Statement (IDS)/PTO-1449 [ ] Copies of IDS Citations
12. [ ] Preliminary Amendment
13. [X] Return Receipt Postcard (MPEP 503)
(Should be specifically itemized)
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PATENT
15-CT-4697

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- Patent Application Transmittal (1 page)
- Fee Transmittal (in duplicate) (1 page)
- Thirteen (13) pages of specification; six (6) pages of claims; one (1) page of abstract
- Nine (9) sheets of drawings
- Declaration and Power of Attorney for Robert F. Senzig (2 pages)
- Declaration and Power of Attorney for Hui David He (2 pages)
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IMAGING SYSTEM FOR GENERATING HIGH QUALITY IMAGES

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 60/114,479, filed December 31, 1998.

BACKGROUND OF THE INVENTION

This invention relates generally to imaging and, more particularly, to scalable multislice imaging systems.

In at least some imaging systems generally referred as computed tomography (CT) systems, an x-ray source projects a fan-shaped beam which is collimated to lie within an X-Y plane of a Cartesian coordinate system and generally referred to as the "imaging plane". The x-ray beam passes through the object being imaged, such as a patient. The beam, after being attenuated by the object, impinges upon an array of radiation detectors. The intensity of the attenuated beam radiation received at the detector array is dependent upon the attenuation of the x-ray beam by the object. Each detector element of the array produces a separate electrical signal that is a measurement of the beam attenuation at the detector location. The attenuation measurements from all the detectors are acquired separately to produce a transmission profile.

In known third generation CT systems, the x-ray source and the detector array are rotated with a gantry within the imaging plane and around the object to be imaged so that the angle at which the x-ray beam intersects the object constantly changes. X-ray sources typically include x-ray tubes, which emit the x-ray beam at a focal spot. X-ray detectors typically include a collimator for collimating x-ray beams received at the detector, a scintillator adjacent the collimator, and photodiodes adjacent the scintillator.

In known third generation CT systems, the x-ray source and the detector array are rotated with a gantry within the imaging plane and around the object to be imaged so that the angle at which the x-ray beam intersects the object constantly changes. A group of x-ray attenuation measurements, i.e., projection data, from the detector array at one gantry angle is referred to as a "view". A "scan" of the object

comprises a set of views made at different gantry angles, or view angles, during one revolution of the x-ray source and detector. In an axial scan, the projection data is processed to construct an image that corresponds to a two dimensional slice taken through the object. One method for reconstructing an image from a set of projection data is referred to in the art as the filtered back projection technique. This process converts the attenuation measurements from a scan into integers called "CT numbers" or "Hounsfield units", which are used to control the brightness of a corresponding pixel on a cathode ray tube display.

To reduce the total scan time, a "helical" scan may be performed. To perform a "helical" scan, the patient is moved while the data for the prescribed number of slices is acquired. Such a system generates a single helix from a one fan beam helical scan. The helix mapped out by the fan beam yields projection data from which images in each prescribed slice may be reconstructed. Total scan time may be further reduced by increasing the number of detector cells in the axis along the patient. An area detector can also be used to collect a volume of data in each rotation.

In a x-ray fluoro system, a flat panel detector can be used to take sequential exposures to track dynamic motion in a patient. This can yield images with high temporal resolution. The images, however, have significant super position artifacts.

In CT fluoroscopic systems ("CT Fluoro"), data collected from a scan may be utilized to generate sequential frames of images. A frame, like a view, corresponds to a two dimensional slice taken through the imaged object. There are no super position artifacts. Particularly, projection data is processed at a frame rate to construct multiple images. With known CT Fluoro systems, the gantry of the CT system is rotated about the area of interest of the patient and sequential images are reconstructed and displayed.

At least one known imaging system utilizes a closed gantry to generate a 3D image of the patient. The 3D images provide object information including depth information. As a result of the closed gantry construction of the CT system, the object is translated through the gantry to generate a 3D image of the object. The translation of the object through the gantry, in addition to being nearly impossible for certain types of objects, causes CT system positioning and use to be difficult.

It would be desirable to provide an multimode imaging system which generates various types of images for the object so that the tradeoffs between devices may be minimized. It also would be desirable to provide such a multimode imaging system which facilitates an open gantry to easy and fast access to the object to be imaged.

BRIEF SUMMARY OF THE INVENTION

These and other objects may be attained by a multimode imaging system which, in one embodiment, includes a substantially C-shaped arm movably coupled to a movable base to reduce difficulty of scanning an object. More specifically, the arm is rotatable and movable relative to the base. A source assembly having a x-ray source and a detector assembly having a detector are movably coupled to the arm. The source assembly and the detector assembly can be independently movable relative to each other and to the arm to adjust image geometry.

In an exemplary embodiment, an operator selects one or more modes of operation of the imaging system. By enabling the system operator to make such selections, different types of image data can be displayed without moving the object or the system. More specifically, and in an exemplary embodiment, the system may be placed relative to the object to be scanned and placed in the selected mode of operation. The movement of the arm and the source and detector assemblies are based upon the mode selected by the operator. Using data collected from the detector, images are generated for the desired area of the object. Images generated in one mode may combined or utilized with images generated in another mode to generate additional images. In another embodiment, the imaging system source and detector may be movably coupled to a large bore rotating gantry.

Additionally, the configuration and the orientation of the detector may be changed to generate additional types of image data. In an exemplary embodiment, the detector includes two detector panels which are angularly positioned relative to each other. Using known references and data collected from the detector panels, specific elements of interest may be located on a 3D image of the object.

The above described multimode imaging system generates various types of images for the object. Such system also enables easy and fast access to the object to be imaged. Such system may be accomplished using a C-arm configuration or with a large bore gantry.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a pictorial side view of an imaging system.

Figure 2 is a pictorial front view of the system illustrated in Figure 1.

Figure 3 is a pictorial view of the system illustrated in Figure 1 representing an altered position of a source and a detector.

Figure 4 is a pictorial side view of the system shown in Figure 1 utilizing a table to support an object.

Figure 5 is a pictorial side view of an alternative position of the system illustrated in Figure 4 and an alternative embodiment of the detector.

Figure 6 is a front view of another embodiment of the detector illustrated in Figure 5.

Figure 7 is pictorial side view of the system illustrated in Figure 1 in a CT volume sliding mode.

Figure 8 is pictorial side view of the system illustrated in Figure 1 in a x-ray fluoro mode.

Figure 9 is pictorial side view of the system illustrated in Figure 1 in a tomosynthesis mode.

DETAILED DESCRIPTION OF THE INVENTION

Referring to Figure 1 and 2 and in one embodiment, a multimode imaging system 10 is shown as including a base 14 and a positioning means 16. In one embodiment, base 14 extends from a portable platform 18 having a plurality of wheels 20, or other similar position altering devices, so that system 10 is movable relative to an object to be imaged (not shown in Figures 1 and 2). In an alternative embodiment, base 14 is movably coupled and extends from a fixed surface, i.e., a wall (not shown). In one embodiment positioning means 16 includes an arm which is movably coupled to base 14 and includes a first end portion 22 and a second end portion 24. More specifically, arm 16 rotates relative to base 14 about an axis of rotation and moves relative to base 14 to alter the respective distances between arm first end portion 22 and base 14 and arm second end portion 24 and base 14. An x-ray

source assembly 26 is movably coupled to arm first end portion 22. X-ray source assembly 26 includes an X-ray source 28 which is configured to emit x-ray signals. A detector assembly 30 is movably coupled to arm second end portion 24. Detector assembly 30 includes a detector 32 and is configured to receive the x-ray signals from said source 28 to generate an image of the object. By moving arm 16 relative to base 14, the position of source assembly 26 may be altered so that source assembly 26 is moved toward or away from base 14. Altering the position of source assembly 26, alters the position of detector assembly 30 relative to base 14 in an opposite direction.

More specifically, source 28 and detector 32 are aligned along a plane of interest 34 with respect to the object. Source assembly 26 and detector assembly 30 each independently move relative to each other to alter plane of interest 34 with respect to the object. Additionally, source assembly 26 and detector assembly 30 are each configured to move independent of each other relative to arm 16 to alter a distance between source 28 and detector 32 so that the geometry of system 10 may be varied. More specifically, the position of source assembly 26 and detector assembly 30 may be varied, or altered, so that the respective distances between a system iso-center and source 28 and detector 32 are altered. As shown in Figure 3, by altering the distance between source 28 and detector 32 and the respective distances to the iso-center of system 10, the magnification factor of system 10 may be modified. The modifiable magnification may be utilized for special imaging needs.

Detector 32, in one embodiment, is formed by a plurality of detector elements 34 which together sense the projected x-rays that pass through the object to collect image data. Detector 32 may be fabricated in a single slice, a multi-slice, or flat panel configuration.

In one embodiment, detector 32 is a solid state detector or radiation imager comprising a large flat panel imaging device having a plurality of pixels 34 arranged in rows and columns. Each pixel 34 includes a photosensor (not shown), such as a photodiode, that is coupled via a switching transistor (not shown) to two separate address lines, a scan line and a data line. In each row of pixels, each respective switching transistor (typically a thin film field effect transistor (FET)) is coupled to a common scan line through that transistor's gate electrode. In each column of pixels, the readout electrode of the transistor (e.g., the source electrode of the FET) is coupled to a data line, which in turn is selectively coupled to a readout amplifier. During nominal operation, x-ray beams 16 passing through the object, for

example a patient, being examined are incident on imaging array 32. The radiation is incident on a scintillator material and the pixel photosensors measure (by way of change in the charge across the diode) the amount of light generated by x-ray interaction with the scintillator. As a result, each detector element, or pixel, 34 produces an electrical signal that represents the intensity of an impinging x-ray beam and hence the attenuation of beam 16 as it passes through the object. During a scan to acquire x-ray projection data in one mode defined as a CT volume rotation mode, detector assembly 30 and source assembly 26 are rotated about the object.

In another embodiment of detector 32, x-rays 16 can directly generate electron-hole pairs in the photosensor (commonly called "direct detection"). The photosensor charge data are read out by sequentially enabling rows of pixels (by applying a signal to the scan line causing the switching transistors coupled to that scan line to become conductive), and reading the signal from the respective pixels thus enabled via respective data lines (the photodiode charge signal being coupled to the data line through the conductive switching transistor and associated readout electrode coupled to a data line). In this way a given pixel can be addressed though a combination of enabling a scan line coupled to the pixel and reading out at the data line coupled to the pixel.

For example, as shown in Figure 4, system 10 includes a table 46 for supporting an object 50, i.e., surgical table for supporting a patient. In one embodiment, where base 14 is movable relative to table 46, system 10 may be positioned along either side or end of table 46. To generate an image of patient 50, arm 16 is rotated so that source assembly 26 and detector assembly 30 rotate about patient 50. More specifically, arm 16 is rotatably coupled to base 14 so that detector 32 and source 28 are rotated about object 50. In one embodiment, images are generated by partially rotating arm 16 around patient 50, i.e., arm 16 is rotated 180 degrees plus a fan angle, i.e., approximately 40 degrees, of source 28 around object 50.

In one embodiment, movement of arm 16 and the operation of x-ray source assembly 26 and detector assembly 30 are governed by a control mechanism 52 of system 10. Controller, or control mechanism, 52 includes an x-ray controller54 that provides power and timing signals to x-ray source 28 and a motor controller 56 that controls the position of arm 16, source assembly 26 and detector assembly 30. A data acquisition system (DAS) 58 in control mechanism 52 samples data from

detector 32 for subsequent processing. An image reconstructor 60 receives sampled x-ray data from DAS 58 and performs high speed image reconstruction. The reconstructed image is applied as an input to a computer 62 which stores the image in a mass storage device 64.

Computer 62 also receives commands and scanning parameters from an operator via a console 64 that has a keyboard. An associated cathode ray tube display 66 allows the operator to observe the reconstructed image and other data from computer 62. The operator supplied commands and parameters are used by computer 62 to provide control signals and information to DAS 58, x-ray controller 54 and motor controller 56. Computer 62 operates a table motor controller 68 which controls position of motorized table 46 relative to system 10.

In one embodiment as shown in Figure 4, detector 32 includes at least one detector panel 100 which is rotatable relative to arm 16. Panel 100 is sized to collect data for an entire organ, section, or region, of object 50, i.e., 40cm by 40cm. The area of object 50 to be imaged may be changed by altering, or rotating, detector 32, specifically, panel 100. More specifically, where the shape of panel 100 is non-symmetrical, i.e., having a non-square shape, the orientation of panel 100 may changed to select between a greater coverage area and a greater field of View (FOV). Particularly, panel 100 may be rotated to select the appropriate coverage area and FOV. In addition and again referring to Figure 3, the area of object 50 to be imaged may be modified by altering the position of detector assembly 30 and/or source assembly 26 so that the distance between source 28 and detector 32 is modified or altered. More specifically, source assembly 26 and detector assembly 30 may be positioned so that only a portion of detector panel 100 is exposed to the x-ray signals emitted from source 28.

In one embodiment, a partially defective panel 100, i.e., known portions of panel elements 34 are non-responsive to x-ray signals, may be utilized to generate images of object 50. This may be accomplished by altering the distance between source 28 and detector 32. Specifically, the distance between source 28 and detector panel 100 is reduced so that the area of x-ray signal exposure is limited to the functioning portion of panel 100. For example, where any number of detector panel elements 34 are non-responsive so that the right 25% of panel 100 is unusable, the distance between detector 32, specifically panel 100, relative to source 28 may be altered so that the data is collected from the remaining 75% of panel 100. In another

embodiment, detector panel 100 and/or source 28 may be positioned so that only the center 50% of panel 100 is utilized and the known defective 25% right and a corresponding 25% of the left side of panel 100 are unused to generate the image. The partially defective panel 100 may also be used by collimating x-ray beam 16 from source 28, using a collimator (not shown), so that the defective portion of panel 100 is not exposed to x-rays 16. As a result, x-ray dose to patient 22 is reduced.

In another embodiment and referring to Figure 5, detector 32 includes a first panel 102 and a second panel 104. Panels 102 and 104, are similar to panel 100 and are rotatable relative to arm 16 to alter the field of coverage and the FOV. In one embodiment, panel 102 is positioned adjacent to second panel 104 so that the area of detector 32 includes a combined surface area of panel 102 and panel 104. In another embodiment as shown in Figure 6, panels 102 and 104 are angularly positioned relative to one another. More specifically and in one embodiment, respective panels 102 and 104 are positioned relative to each other so that the surface of panel 102 is at an obtuse angle with reference to the surface of panel 104. In other embodiments, the angle between respective panels 102 and 104 may range from approximately 0 degrees to approximately 30 degrees. For example, in one embodiment panel 102 is positioned perpendicular to panel 104.

In operation, system 10 is configured to operate in at least one of a plurality of modes including for example, Computed Tomography (CT) volume axial rotating, CT volume helical rotating, CT volume sliding, X-ray Fluoro, and CT tomosynthesis modes. Initially an operator determines, or selects, a first, or initial, mode of operation for system 10, for example using computer 62. The position and movement of arm 16, source assembly 26 and detector assembly 30 are based on the selected mode of operation of system 10. More specifically, the position and movement of arm 16 relative to base 14 and source assembly 26 and detector assembly 30 relative to each other, arm 16, and the object are altered, or controlled, by the operator selected mode. After collecting data utilizing detector assembly 30, at least one image of object 50 is generated. The operator may then generate additional images using existing mode or may select one of the other modes of system 10. The operation of system 10 for the CT volume rotating, CT volume sliding, CT fluoro, and CT tomosynthesis modes are described below in further detail below.

CT Volume Rotating

Prior to selecting the CT volume rotating mode of system 10 by the operator, system 10 is positioned relative to object 50. As a result of the shape of arm 16, system 10 may be easily positioned adjacent to table 46. For example and referring again to Figure 5, as shown in Figure 6, where images are desired of a certain area of object 50, i.e., the lower portion of a patient's leg, system 10 is placed relative to table 46 so that arm 16 rotates about table 46. More specifically, system 10 is positioned near the end of table 46 so that as arm 16 rotates about a Z axis of object 50, source assembly 26 and detector assembly 30 move relative to table 46. Particularly and in one embodiment, arm 16 rotates about 180 degrees plus a fan angle about base 14. Arm 16 is rotated relative to base 14, source assembly 26 and detector assembly 30 are rotated about object 50 and table 46. X-rays signals are emitted from source 28 and collected by detector 32 as arm 16 is rotated. The signals collected from detector 32 are processed in a manner known in the art to generate an image of object 50, i.e., an image along the plane of interest of the patient's leg. More specifically and in one embodiment, arm 16 rotates about base 14 at a fairly slow speed, i.e., 3 to 10 seconds per rotation, and data is collected for each row of elements 32. Reconstructed images are then generated using data collected from elements 34 of detector 32. In one embodiment, the reconstructed images for each row of detector 34 are then combined to form a 3D image of object 50. The 3D image, in one embodiment, is a volume display, to understand the location of the elements contained within object 50, for example the bones within the patient. As described above, where detector 32 is non-symmetrical, the orientation of detector 32 may be altered to select the appropriate coverage area, i.e., a larger X-axis coverage area, and Field of View (FOV), i.e., a larger Z-axis coverage area. After the images are generated, the operator may reposition system 10 relative to object 50 or select a different mode of operation. In addition, if the operator has completed all tasks, system 10 may be removed without interfering with or disturbing object 50.

CT Volume Sliding

The CT volume sliding mode allows image generation of objects having a shape, placement, or configuration which are difficult or impossible to image using known imaging systems. More specifically, and as shown in Figures 4 and 7 where system 10 is placed along one of the sides of table 46, arm 16 is moved relative to base 14 so that source assembly 26 and detector assembly 30 are moved perpendicular to table 46. Particularly, as arm 16 is moved relative to base 14, source assembly 26 and detector assembly 30 traverse around object 50 so that plane of

interest 34 is parallel to surface 52 of table 46. For example as shown in Figure 5, in order to scan object 50 positioned on table 46, arm 16 is moved relative to base 14 so that the respective distances between arm first end portion 22 and base 14 and between second end portion 24 and base 14 are altered. More specifically and in one embodiment, arm 16 is moved relative to base 14 so that source assembly 26 is a maximum distance from base 14 and detector assembly is a minimum distance from base 14.

To generate an image of object 50, source 28 is enabled to emit x-ray signals toward detector 32 and arm 16 is moved relative to base 14 so that source assembly 26 is moved closer to base 14. In one embodiment, arm 16 is moved relative to base 14 so that source assembly 26 and detector assembly 30 scan 180 degrees plus a fan angle of source 28 traverse to object 50. 3D images are then generated in a similar manner as described above in the CT volume rotating mode. After the images are generated, the operator may reposition system 10 relative to object 50 or select a different mode of operation. In addition, if the operator has completed all tasks, system 10 may be removed without interfering with or disturbing object 50.

X-ray Fluoro Mode

Once at least one 3D image has been generated for object 50 using one of the other modes, system 10 is placed into the X-ray fluoro mode to locate in elements within object 50. In one embodiment as shown in Figure 7, where system 10 is positioned along one side of table 46, arm 16 is positioned relative to object 50 and is fixed in position, i.e., arm 16 is positioned so that plane of interest 34 is parallel to base 14 and source assembly 26 and detector assembly 30 are an equidistance from base 14. The distance between source 26 and detector 30 is then adjusted for the selected area to be scanned. Source 28 is then enabled and image data is collected. Source 28 can then be translated along the Z axis of object 50, i.e., the patient, to locate the desired element within the object, i.e., a bone of interest, as the position of detector 32 remains fixed. As source 28 is translated, a series of real-time images along plane of interest 34 are generated in accordance with known fluoroscopy methods to determine the location of the desired element within object 50. A pseudo three dimensional image may then be generated by combining multiple images taken at different angles. This will yield additional depth information not found in a conventional single position image.

In another embodiment, source 28 is angularly translated relative to object 50 to determine the location of the bones of interest in the 3D image. More specifically, source 28 is shifted, or moved, toward or away from detector assembly 30 in addition to the Z-axis translation so that source 28 is angularly translated relative to object 50 to generate the real-time images.

In another embodiment, the location of the desired elements, i.e., bones of interest, may be directly determined using data collected from detector panels 102 and 104. More specifically and referring to Figure 6, where respective panels 102 and 104 are angularly positioned relative to one another, separate images are generated for respective panels 102 and 104. After determining the location of known references in the separate images generated from panels 102 and 104, the location of the bones of interest on the 3D image are directly determined utilizing known triangulation methods. More particularly and in one embodiment, utilizing a dual spot source 28 and linear translation of source 28, the location on the 3D images is determined.

For example, after generating the 3D images using one of the CT volume modes, the operator places system 10 in the fluoro mode. Using the generated fluoro mode real-time images, the operator, for example a doctor, may locate at least one bone of interest. In addition, the fluoro images may be utilized to display and determine the location of other devices with respect to the bone of interest. For example, the image may be utilized to locate medical screws to be inserted into the bone of interest. Specifically, the images may be utilized to predict, or determine, the trajectory of a medical instrument, for example, a drill, with respect to the bone of interest. This may also be accomplished by instructing the screw or instrument position device. After the images are generated, the operator may reposition system 10 relative to object 50 or select a different mode of operation. In addition, if the operator has completed all tasks, system 10 may be removed without interfering with or disturbing object 50.

Tomosynthesis Mode

In the tomosynthesis mode, at least one plane of interest image is generated using system 10. Specifically and referring to Figure 9, each plane of interest image includes a single plane of the object which is in focus and all remaining information contained in the image is blurred. More specifically and in one embodiment, source assembly 26 and detector assembly 30 are positioned so that plane of interest 34 is aligned with the desired object image plane of interest. In

another embodiment, a series of plane of interest images are generated by translating source assembly 26 and detector assembly 30 together parallel to the desired object plane of interest. For example, where system 10 is placed along one side of table 46 and plane of interest 34 is perpendicular to table 46, source assembly 26 and detector assembly 30 are translated together along the Z axis of object 50 to generate an image of each desired plane of interest 34. In another embodiment, source 28 may be angularly translated as described above, as detector assembly 30 is translated to generate the series of images. In one embodiment, the series of plane of interest images are then digitally combined to generate a stack of images representative of the image volume.

Use

In use, system 10 may be utilized to generate different types of images and information for object 50. For example in medical applications, a patient 50 lying on table 46, i.e., an emergency room table or a surgical table, may be scanned. As a result of the portability of system 10 and the shape of arm 16, system 10 may be quickly positioned relative to patient 50 without interfering with the numerous devices which are typically coupled to patient 50. In addition, system 10 may be positioned in a plurality of positions to scan the desired area of patient 50 without moving patient 50. Additionally, the mode of system 10 may be altered to generate different types of images to provide further assistance in providing aid to patient 50. More specifically and in one embodiment, an operator selects at least one mode of operation for system 10 utilizing the keyboard. Computer 62 supplies the appropriate signals to control mechanism 52 control the movement of positioning means 16, source assembly 26, and detector assembly 30. In addition, where the operator desires to generate an image utilizing more than one mode, the operator may select at least additional mode using computer 62. More specifically, the operator may configure system 10 so that at least one image from a first mode of operation may be combined with at least one image from at least a second mode of operation. As a result of the combination of the images, image quality is improved.

In industrial applications, system 10 may be utilized to generate images for objects which are typically difficult or impossible to scan. For example, a piece of equipment that is fixed in position and coupled to other equipment may be scanned using system 10. Specifically, as a result of the shape of arm 16, source 28 and detector 32 may be utilized to generate images of the object.

In another embodiment of system 10, positioning means 16 is a large bore gantry (not shown). Gantry 16 is rotatably coupled to base 14 and source assembly 26 and detector assembly 30 are movably coupled to gantry 16. In one embodiment, gantry 16 includes a large bore (not shown) of approximately 80 to over 100 cm in diameter. The large bore provides adequate clearance to scan a patient 50 positioned on a large surgical table (not shown). In addition to altering the position of source assembly 26 and detector assembly 30 as described above, gantry 16 rotates source assembly 26 and detector assembly 30 around patient 50.

The above described multimode imaging system generates various types of images for the object. Such system also enables easy and fast access to the object to be imaged. Such system may be accomplished using a C-arm configuration or with a large bore gantry.

From the preceding description of various embodiments of the present invention, it is evident that the objects of the invention are attained. Although the invention has been described and illustrated in detail, it is to be clearly understood that the same is intended by way of illustration and example only and is not to be taken by way of limitation. Accordingly, the spirit and scope of the invention are to be limited only by the terms of the appended claims.

WHAT IS CLAIMED IS:

1. A method of generating an image of an object using a multimode imaging system configured to operate in at least one of a plurality of modes of operation, the multimode imaging system including a source assembly, a detector assembly, and a means for positioning the source assembly and the detector assembly, the source assembly coupled to the means for positioning and including an x-ray source configured to emit x-ray signals, the detector assembly coupled to the means for positioning and including a detector, said method comprising the steps of:

selecting at least one mode of operation;

positioning the source assembly and the detector assembly for each determined mode of operation;

generating an image of the object for each determined mode of operation.

2. A method in accordance with Claim 1 wherein selecting at least one mode of operation, said method comprises the step of selecting at least one of a computed tomography mode, an x-ray mode, a fluoroscopy mode, a tomosynthesis mode, and a volume computed tomography mode.

3. A method in accordance with Claim 1 wherein positioning the source assembly and the detector assembly, said method comprises the step of rotating the detector assembly and the source assembly about the object.

4. An imaging system for generating an image of an object, said imaging system configured to operate in at least one of a plurality of modes of operation and comprising:

a source assembly comprising a movable x-ray source configured to emit x-ray signals;

a detector assembly comprising a movable detector;

a positioning means for positioning said source assembly and said detector assembly relative to the object, said source assembly movably coupled to said positioning means and said detector assembly movably coupled to said positioning means; and

a controller enabling an operator to selectively operate said system in at least one of a plurality of modes.

5. A method in accordance with Claim 4 wherein said plurality of modes comprises at least one of a computed tomography mode, an x-ray mode, a fluoroscopy mode, a tomosynthesis mode, and a volume computed tomography mode.

6. An imaging system in accordance with Claim 4 wherein said source is configured to move relative to said positioning means to alter a distance from said source to said detector.

7. An imaging system in accordance with Claim 4 wherein said detector is configured to move relative to said positioning means to alter a distance from said detector to said source.

8. An imaging system in accordance with Claim 4 wherein said source and said detector are aligned along a plane of interest, and wherein at least one of said source and said detector configured to move relative to other said assembly and said positioning means to alter said plane of interest.

9. An imaging system in accordance with Claim 4 further comprising a table for supporting the object, said source and said detector are movable relative to said table.

10. An imaging system in accordance with Claim 9 wherein said positioning means is movable relative to said table.

11. An imaging system in accordance with Claim 4 wherein said detector comprises at least one detector panel.

12. An imaging system in accordance with Claim 11 wherein at least one said detector panel is rotatable relative to said positioning means.

13. An imaging system in accordance with Claim 11 wherein said detector comprises a first detector panel and a second detector panel.

14. An imaging system in accordance with Claim 13 wherein said first detector panel is angularly positioned relative to said second detector panel.

15. An imaging system in accordance with Claim 4 wherein said positioning means comprises a base and an arm movably coupled to said base.

16. An imaging system in accordance with Claim 15 wherein said arm comprises a first end portion and a second end portion wherein said x-ray source assembly coupled to said arm first end portion, and wherein said detector assembly coupled to said arm second end portion.

17. An imaging system in accordance with Claim 4 wherein said positioning means comprises a base and a gantry rotatably coupled to said base.

18. An imaging system for generating an image of an object, said imaging system comprising a base, a positioning means movably coupled to said base, an x-ray source assembly comprising an x-ray source configured to emit x-ray signals and coupled to said positioning means, and a detector assembly comprising a detector coupled to said positioning means, said system configured to:

enable an operator to select a mode of operation;

alter the position of said detector assembly and said source assembly relative to said other assembly and the object based on the selected mode; and

generate an image of the object.

19. A system in accordance with Claim 18 wherein to enable the operator to select a mode, said system is configured enable the operator to select at least one of a computed tomography mode, an x-ray mode, a fluoroscopy mode, a tomosynthesis mode, and a volume computed tomography mode.

20. A system in accordance with Claim 18 wherein to alter the position of said detector assembly and said source assembly, said system is configured to rotate said positioning means relative to said base so that said detector assembly and said source assembly are rotated about the object.

21. A system in accordance with Claim 18 wherein to alter the position of said detector assembly and said source assembly, said system is configured to move at least one of said source and said detector relative to said other assembly to alter a distance between said source and said detector.

22. A system in accordance with Claim 18 wherein said source and said detector are aligned along a plane of interest, and wherein to alter the position of said detector assembly and said source assembly, said system is configured to move at least one of said source and said detector relative to said other assembly to alter the plane of interest.

23. A system in accordance with Claim 22 wherein to move at least one of said source and said detector relative to said other assembly, said system is configured to translate at least one of said source and said detector parallel to the plane of interest.

24. A system in accordance with Claim 18 further comprising a table for supporting the object, and wherein to alter the position of said detector assembly and said source assembly, said system is configured to move said detector and said source relative to said table.

25. A system in accordance with Claim 24 wherein to move said detector assembly and said source assembly relative to said table, said system is configured to rotate said detector assembly and said source assembly about said table.

26. A system in accordance with Claim 18 wherein to generate an image of the object, said system is configured to radiate x-ray signals from said x-ray source toward said detector.

27. A system in accordance with Claim 26 wherein to generate an image of the object, said system is further configured to collect image data.

28. A system in accordance with Claim 27 wherein said detector assembly comprises at least one detector panel, and wherein to collect image data, said system is configured to detect x-ray signals utilizing a portion of at least one of said detector panel.

29. A system in accordance with Claim 28 wherein to detect x-ray signals utilizing a portion of at least one of said detector panel, said system is configured to alter a position of at least one of said detector panel.

30. A system in accordance with Claim 26 wherein said detector assembly comprises a first detector panel and a second detector panel, and wherein to collect image data, said system is configured to angularly position said first detector panel relative to said second detector panel.

31. A system in accordance with Claim 30 wherein to angularly position said first detector panel relative to said second detector panel, said system is configured to position said first detector panel at an obtuse angle relative to said second detector panel.

32. A system in accordance with Claim 30 wherein to angularly position said first detector panel relative to said second detector panel, said system is configured to position said first detector panel at an acute angle relative to said second detector panel.

33. A system in accordance with Claim 30 wherein to angularly position said first detector panel relative to said second detector panel, said system is configured to position said first detector panel perpendicular to said second detector panel.

34. A system in accordance with Claim 18 wherein said positioning means comprises an arm having a first end portion and a second end portion, wherein said x-ray source assembly coupled to said arm first end portion, and wherein said detector assembly coupled to said arm second end portion.

35. A system in accordance with Claim 18 wherein said positioning means comprises a gantry rotatably coupled to said base.

IMAGING SYSTEM FOR GENERATING HIGH QUALITY IMAGES

ABSTRACT OF THE DISCLOSURE

The present invention, in one form, is a multimode imaging system which, in one embodiment, includes a substantially C-shaped arm movably coupled to a movable base to reduce difficulty of scanning an object. A source assembly having a x-ray source and a detector assembly having a detector are movably coupled to the arm. The source assembly and the detector assembly are independently movable relative to each other and to the arm. In one embodiment, an operator selects one or more modes of operation of the imaging system so that various types of image data are displayed.

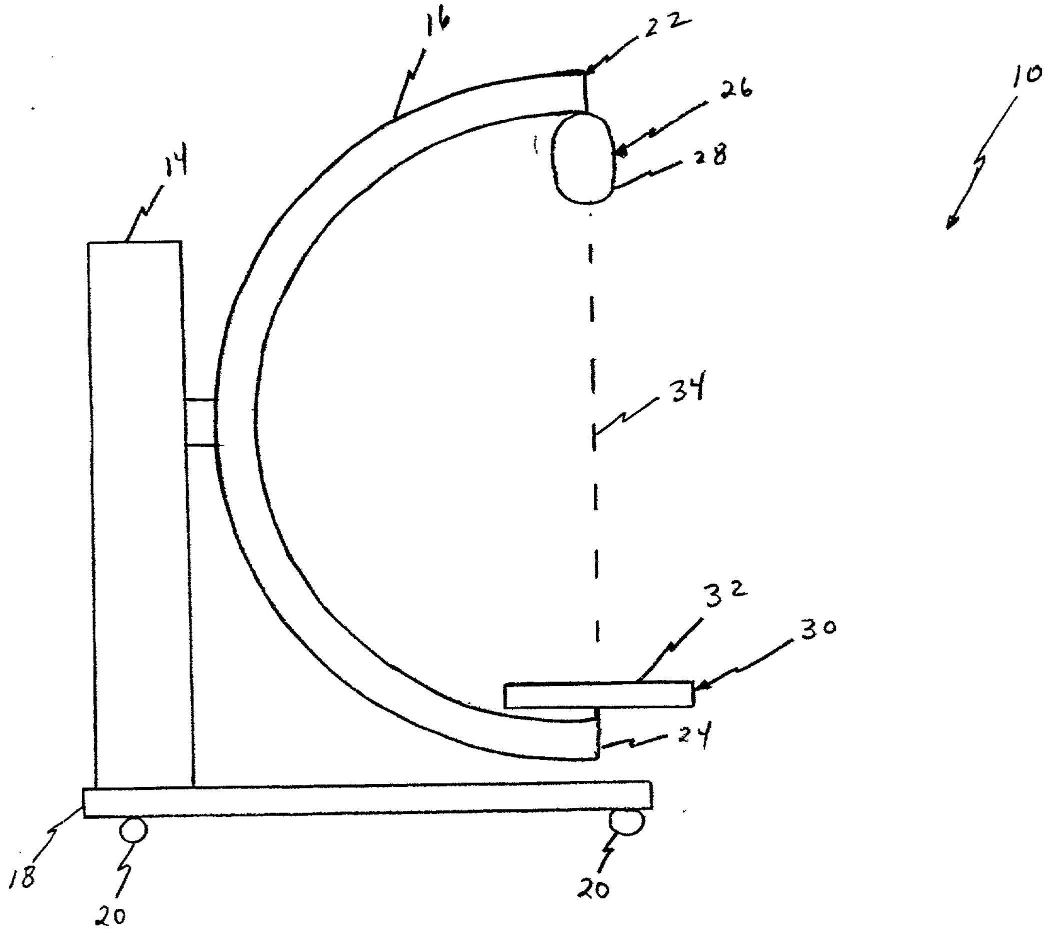


FIG. 1

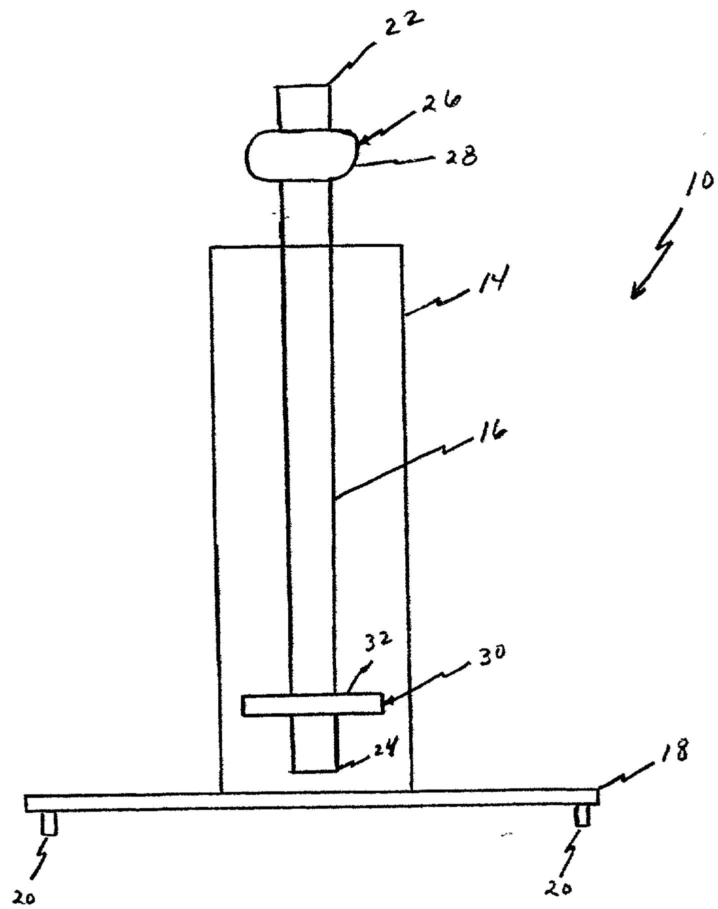


FIG. 2

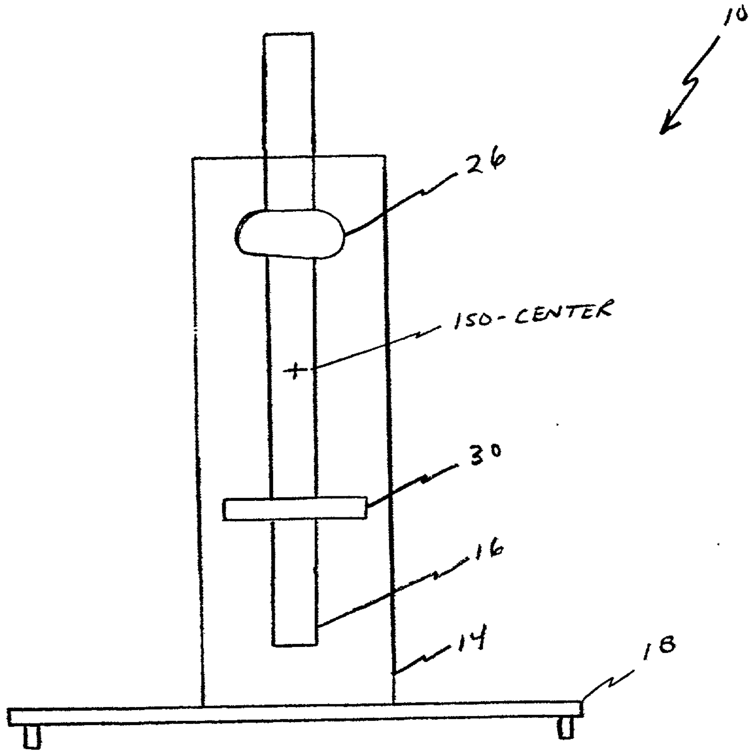
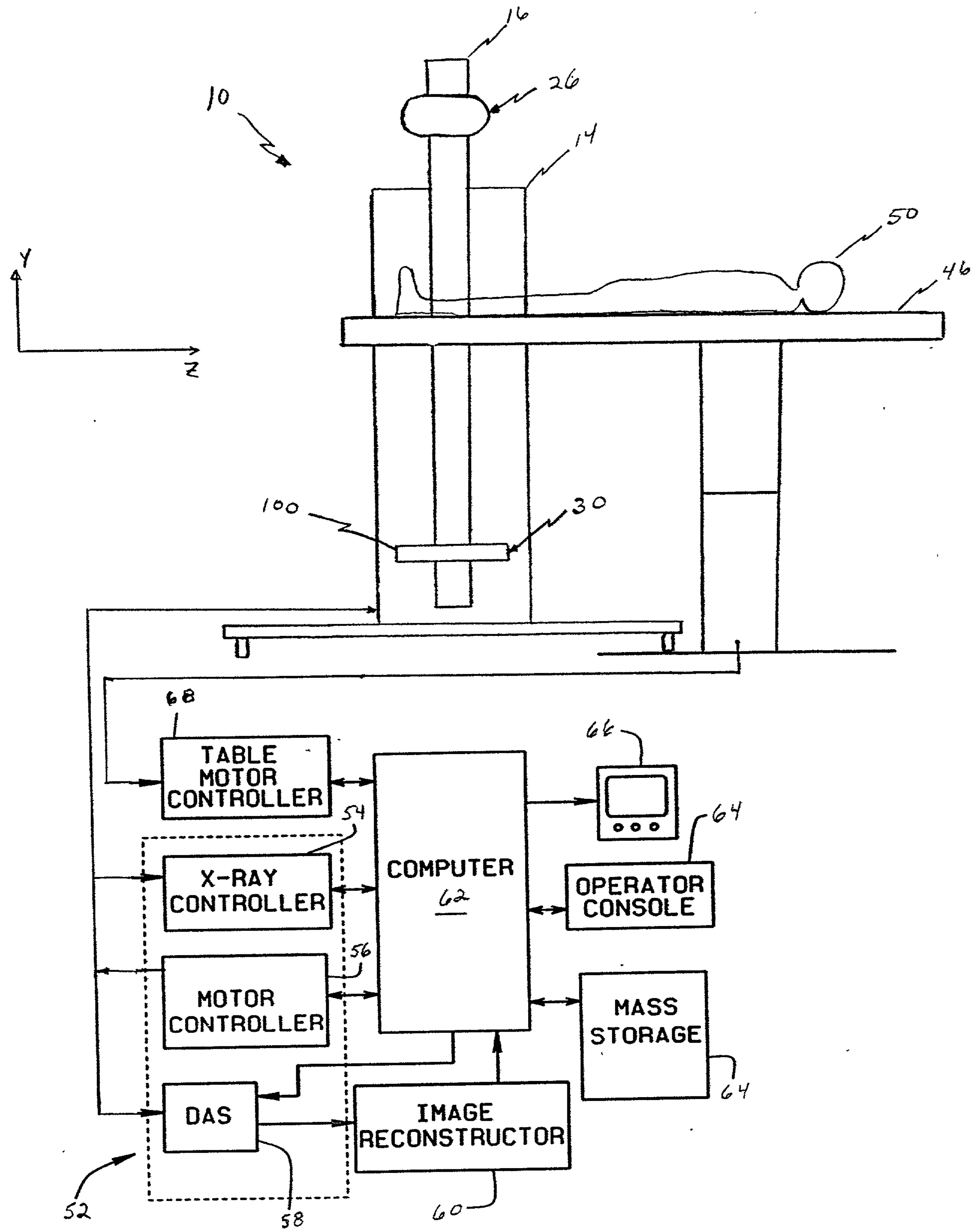


FIG. 3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14
50
46
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Z
100
30
68
TABLE MOTOR CONTROLLER
66
64
54
X-RAY CONTROLLER
COMPUTER 62
OPERATOR CONSOLE
56
MOTOR CONTROLLER
MASS STORAGE
64
DAS
IMAGE RECONSTRUCTOR
52
58
60

FIG. 4

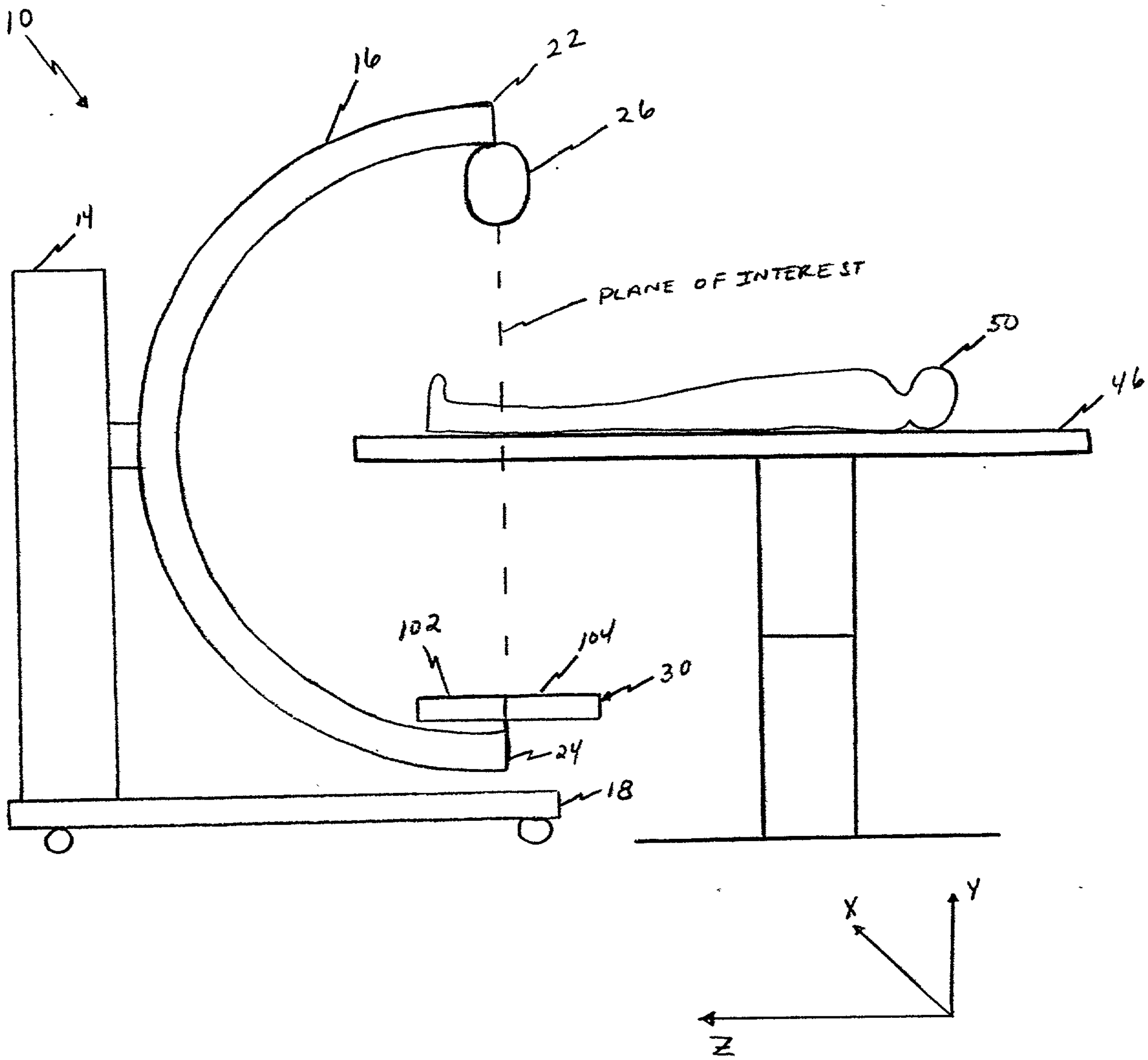

FIG. 5

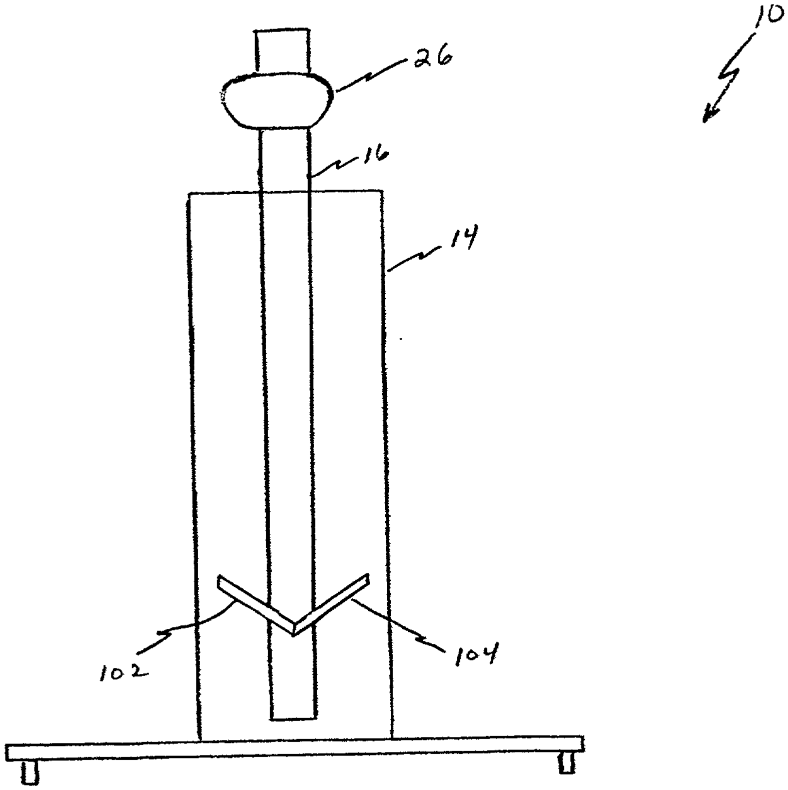

FIG. 6

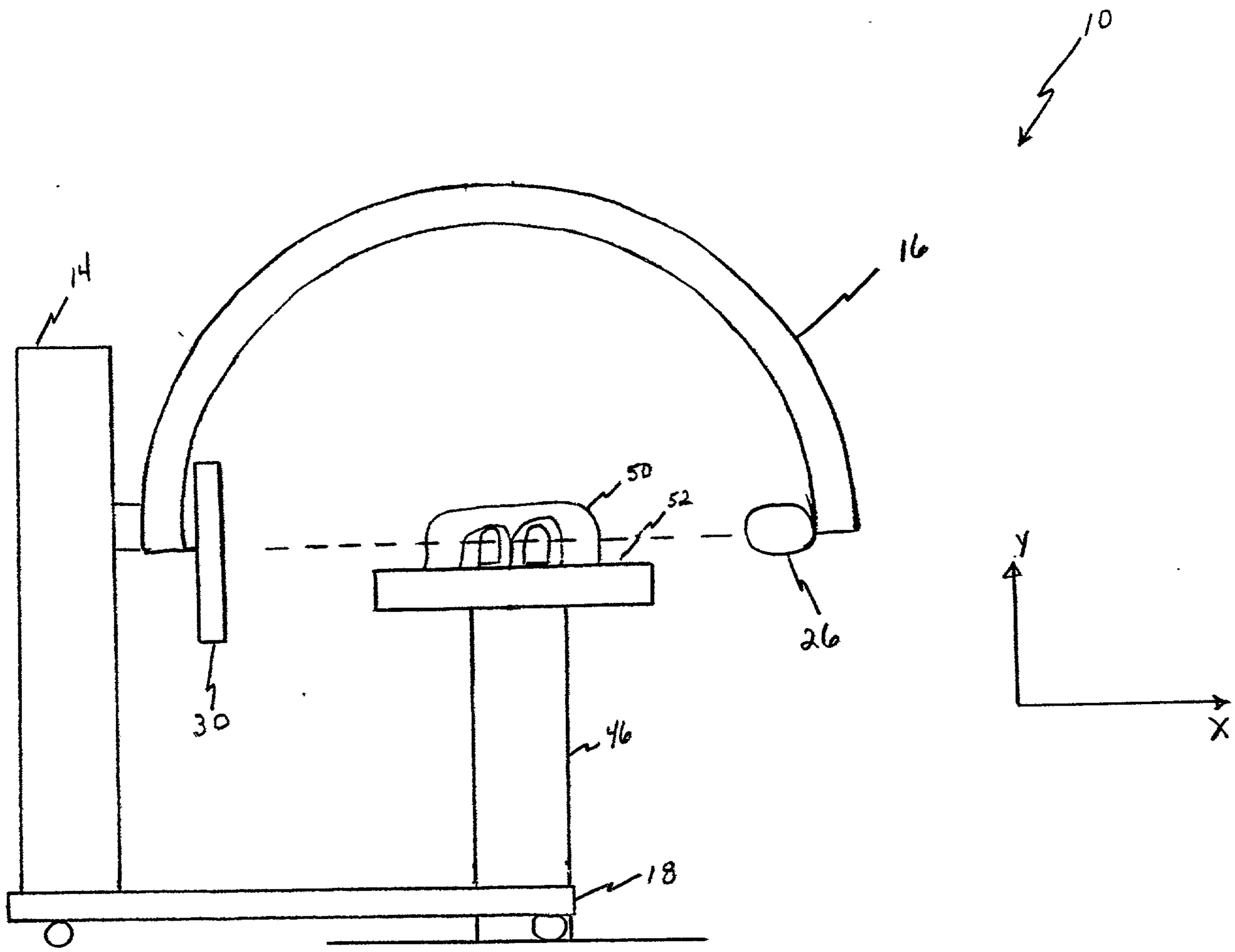

FIG. 7

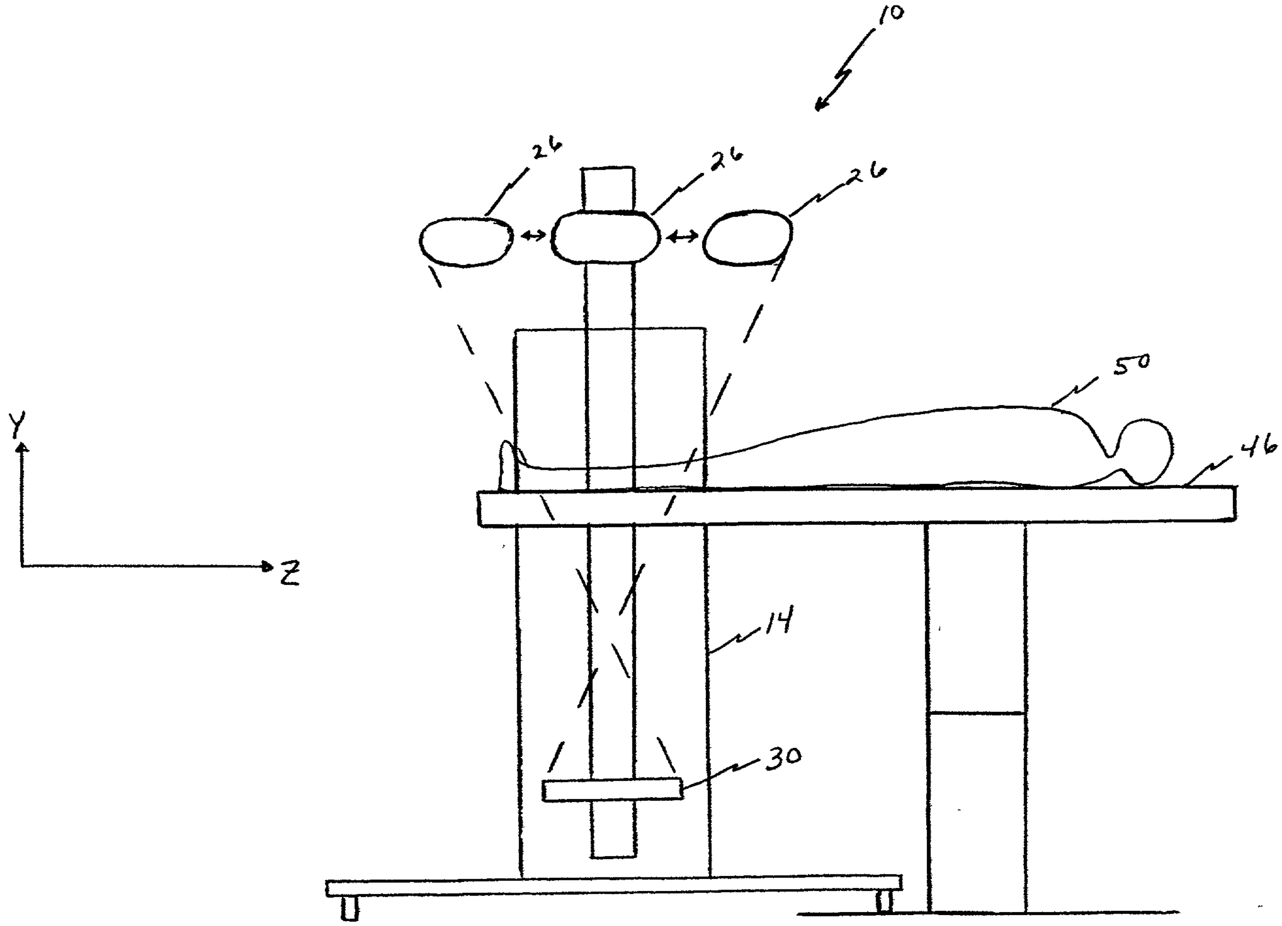

FIG 8

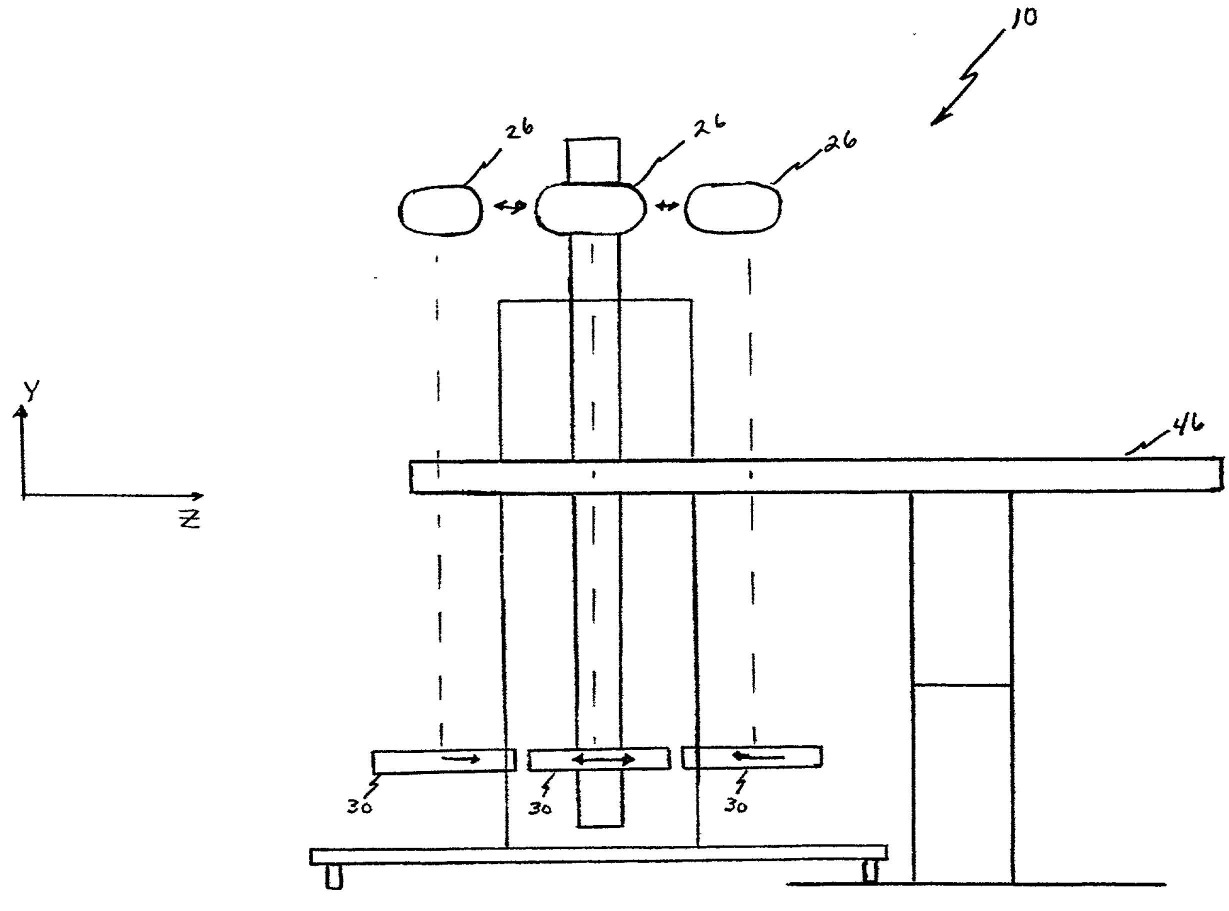

FIG. 9

Express Mail No. EL319727646US

DECLARATION AND POWER OF ATTORNEY	Attorney's Docket No. **15-CT-4697**

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled: **IMAGING SYSTEM FOR GENERATING HIGH QUALITY IMAGES**, the specification of which:

(check one) [✓] is attached hereto

[ ] was filed on ____________ as Application Serial No. __________,
and was amended on ______________________.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations §1.56(a).

I hereby claim priority benefits under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112. I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

Application Serial No.	Filing Date	Status (patented, pending, abandoned)

I hereby claim the benefit under Title 35, United States Code §119(e) of any United States provisional application(s) listed below:

Application Serial No.	Filing Date
60/114,479	December 31, 1998

_____ Additional provisional application numbers are listed on a supplemental priority sheet attached hereto.

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith. (*list name and registration number)*

John S. Beulick (Reg. No. 33,338), and Alan L. Cassel (Reg. 35,842) of Armstrong Teasdale LLP, One Metropolitan Square, Suite 2600, St. Louis, MO 63102-2740; Phyllis Y. Price (Reg. No. 34,234) and Christian G. Cabou (Reg. No. 35,467), of GE Medical Systems, 3000 North Grandview Blvd., W-710, Waukesha, WI 53188; Jay Chaskin (Reg. No. 24,030); Ronald E. Myrick (Reg. No. 26,315) and Henry J. Policinski (Reg. No. 26,621), of General Electric Company (W3C), 3135 Easton Turnpike, Fairfield, CT 06431-0001

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DECLARATION AND POWER OF ATTORNEY	Attorney's Docket No. 15-CT-4697

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application and any patent issued thereon.

SOLE OR FIRST INVENTOR:

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Signature: Date:

Residence: Waukesha, Wisconsin 53188

Citizenship: China

Post Office Address: 2806 Lincolnshire Court, Waukesha, WI 53188

Express Mail No. EL319727646US

DECLARATION AND POWER OF ATTORNEY	Attorney's Docket No. 15-CT-4697

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

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(check one) [✓] is attached hereto

[ ] was filed on ____________ as Application Serial No. __________,
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SOLE OR FIRST INVENTOR:

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Signature: __________ Date: __________

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SECOND JOINT INVENTOR, IF ANY:

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Signature: __________ Date: 11/08/99

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